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ORIGINAL ARTICLE

Evaluation of the airway space changes after extraction of four second premolars and orthodontic space closure in adult female patients with bimaxillary protrusion – A retrospective study

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KEYWORDS

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Abstract *Background & objectives:* Previous studies have found that first premolar extractions during orthodontic treatment may alter the upper airway dimensions. The objective of this study is to investigate the effects of second premolar extraction during orthodontic treatment on the dimensions of the upper airway in a sample of female adults.

Methods: Twenty-nine female adult patients with ages between 18 and 30 years old and incisor bimaxillary protrusion were included in this study. They were treated with comprehensive orthodontic treatment which included the extraction of four second premolars. Pre and post cephalometric radiographs were analyzed using Dolphin imaging software for changes in tongue length and height, soft palate thickness and length, the superior, middle, and inferior airway space, and vertical airway length. Descriptive statistics were used to characterize measurements. Student's paired *t*-test was preformed to compare the pre- and post-test mean values of the dimensions.

Results: A significant increase in the vertical airway length was observed after the extraction of the second premolars ($p = 0.02$). The soft palate length showed a tendency towards an increase that did not reach statistical significance ($p = 0.053$). No other significant changes in the airway soft tissue measurements were observed. The proclination and protrusion of the upper and lower incisors were significantly decreased compared to pre-treatment measurements.

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Interpretation & conclusions.

Orthodontic treatment involving the extraction of all four second premolars in females with bimaxillary protrusion increases the vertical airway length, which is the amount of distance between base of the tongue and posterior nasal spine. No other significant alterations in the upper airway measurements were observed.

1. Introduction

The extraction of premolar teeth is a frequently performed procedure as part of orthodontic treatment. Indications for premolar extraction can include certain malocclusions such as dental crowding, dental impactions, increased overjet, orthognathic camouflage and maxillary and mandibular dentoalveolar protrusions (Lopes Filho et al. 2015, Vitalyos et al. 2018, Scott Conley and Jernigan, 2006, Bills et al., 2005). Dentoalveolar bimaxillary protrusion is an occlusion characterized by an increased anterior inclination of the incisors, tendency for lip protrusion and lip incompetence, decreased nasolabial angle and increased facial convexity (Bills et al., 2005) These features are typically deemed functionally and esthetically undesirable by patients, which in turn seek to address through orthodontic treatment (Bills et al., 2005, Samsonyanova and Broukal, 2014). The treatment of bimaxillary protrusion is typically done by extracting 4 premolars, followed by extraction space closure in which incisors and canines are retracted and retroclined to decrease the amount of incisor and lip protrusion.

The changes in the surrounding structures of the upper airway due to the extraction of premolars have generated a significant amount of research interest in the recent years (AlKawari et al., 2018, Sharma et al., 2014, Germec-Cakan et al., 2011). This is due to the perceived possibility of these treatments to cause unintended negative consequences in patient breathing capacity or predispose to conditions such as obstructive sleep apnea (OSA)(Hu et al., 2015). A study by Chen and his coworkers have found that premolar extractions resulted in an alteration in the in the location of the hyoid bone, which its retraction correlated with a reduction in the size of the upper airway. This is also the finding from a study by Wang et al. which observed hyoid retraction, a decrease in the area behind the soft palate and uvela (Chen et al., 2012, Wang et al., 2012, Germec-Cakan et al., 2011). However, studies by Al Maaitah et al. (2012), Stefanovic et al. (2013), Maurya et al. (2019) who found no significant changes to the airway dimensions after extractions.

In the literature, we have a relative abundance of studies which have investigated the effects of the combination of first premolar extractions and fixed appliances therapy on the upper airway dimensions. However, no studies to date have investigated the changes resulting from second premolar extraction as part of orthodontic treatment on the dimensions of the upper airway. Henceforth, the goal of this retrospective study is to examine second premolar extraction effects on the dimensions and measurements of the upper airway in a sample of female orthodontic patients.

2. Materials and methods

2.1. The study sample

The study methodology was reviewed and approved by the Institutional Review Board at King Saud University (approval number E-18-3029). The study sample would include female patients aged between 18 and 30 years old attending the orthodontic clinics at the Dental University Hospital, King Saud University who met the following criteria:

1. Patients having a Class I molar classification with a maxillary and mandibular incisor angle measuring less than 118° (Aldrees and Shamlan, 2010).
2. Four second premolars were extracted and treatment consisted of fixed orthodontic appliances followed by the retraction of anterior teeth
3. A set of diagnostic acceptable pre and post orthodontic treatment cephalometric x-rays were taken.
4. No functional appliances were used and no surgeries were performed.
5. With the exception of the third molars, no congenitally missing teeth.

No reported past medical history of obstructive sleep apnea, snoring, adenoidectomy, tonsillectomy, nasal obstruction or pharyngeal pathologies.

Based on data from previous studies, and choosing a statistical power of 80% with 95% confidence level, the calculated sample size calculated was to be about 28 patients (Entrenas et al., 2019, Al Maaitah et al., 2012). Included patients had their treatment performed by one orthodontist utilizing 0.022″ slot Synergy brackets (Rocky Mountain Orthodontics, Denver, CO) utilizing Roth's prescription. Pre and post treatment digital lateral cephalometric radiographs were obtained as regular records of orthodontic treatment. All cephalometric radiographs were taken with the patient situated in a natural head position, teeth in maximum intercuspation, and the lips relaxed as described by Burstone (1967). Reciprocal space closure was used to close the extraction spaces for these cases using elastomeric chains and sliding mechanics. Treatment time period was no longer than 24 months.

2.2. Data collection and measurements

Analysis of the Cephalometric radiographs were done using Dolphin Imaging Software v10.0 (Dolphin Imaging and Management Solutions, Chatsworth, CA). Magnification was controlled by calibrating the software using the ruler markings on the cephalometric head positioner. Afterwards, landmark identification was done on the digital images manually, and linear measurements were done.

2.3. Airway space and incisor changes

As described by Abu Allhaija and Al-Khateeb (2005), a total of 6 cephalometric anatomical landmarks were included (Fig. 1) and two cephalometric reference planes were used in this study, the mandibular plane and the tongue plane. Afterwards, eight linear readings were measured as described in Table 1 along with maxillary and mandibular incisor inclination and protrusion.

2.4. Statistical analysis

All statistical tests were performed using Stata 14.2 software (StataCrop, College Station, TX). Quantitative variables were described using means and standard deviations. The pre- and post-test mean values of the quantitative variables were compared using Student's paired *t*-test. Statistical significance set at 5% and 95% confidence intervals were used to report the results.

For reliability testing, six randomly selected cephalometric radiograph pairs were selected. The same investigator did landmark identification and cephalometric tracing and measurements. These were done in two sperate instances two weeks apart. A two-way mixed-effect intraclass correlation assessment was utilized to test the reliability of the measurements.

3. Results

The means of the pre-treatment and post-treatment airway measurements are shown in Table 2. Also, the means of pre-treatment and post-treatment dental changes are shown in Table 3. The vertical airway length significantly increased by 1.47 mm after the extraction of the second premolars compared to pre-treatment dimensions ($p = 0.02$). A an increase in the length of the soft palate by 1.3 mm was observed in the post-treatment measurements, but it is below statistical significance ($p = 0.053$). Changes in the tongue length and height, soft palate thickness, and the superior, middle and inferior airway spaces were not significant. All measurements of upper and lower incisor proclination and protrusion were significantly reduced after treatment. A high degree of reliability was found between pre and post-treatment measurements. Average measure ICC was 0.841 or higher ($p < 0.009$).

4. Discussion

The aim of this retrospective investigation was to study the changes in the airway due to the extraction of all four second premolars for those who are undergoing orthodontic treatment for bimaxillary protrusion. For first premolar extraction, it has been found that it results in anterior teeth retraction with about 56% to 66% of the extraction space being occupied by the anterior segment, with the rest taken up with the posterior segment mesial movement (Williams and Hosila, 1976). This amount of anterior retraction is the reason for the first

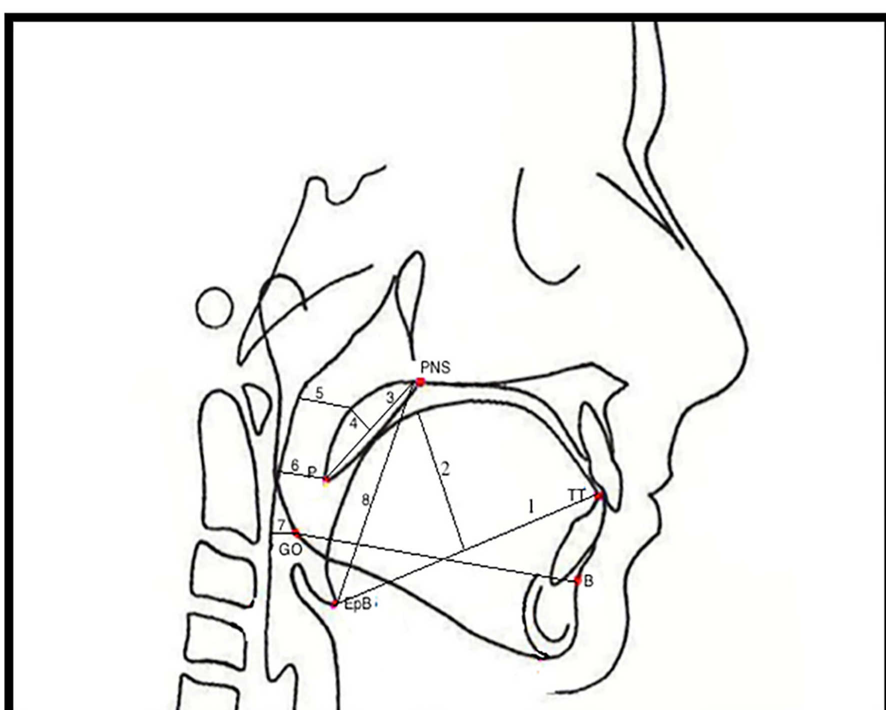

Fig. 1 Cephalometric landmarks and planes used in the cephalometric analysis (adapted from Abu Allhaija and Al-Khateeb, 2005). **PNS**: The posterior tip of the nasal spine of the palatal bone comprising the hard palate. **B**: deepest concavity of the anterior symphysis. **Go:** (Gonion) The most posterior, inferior point on the mandibular angle. **P**: Tip of Uvula. **TT**: Tip of the tongue. **EpB**: Base of the Epiglottic fold; deepest point in the epiglottic fold. Reference line definitions and measurements are in Table 1.

Table 1 Abbreviations and definitions of the cephalometric planes and linear measurements performed on the pre-and post-treatment lateral cephalometric radiographs.

Reference line	Abbreviation	Definition
	Go-B line	The tongue plane; line from point B to Gonion
Tongue measurements	1. (TGL) Tongue Length	Line extending from TT to EpB
	2. (TGH) Tongue Height	Perpendicular line to TGL extending to the tongue dorsum; it represents the maximum thickness of the tongue
Soft palate	3. (PNSP) soft palate length	Line extending from the PNS to P
	4. (MPT) soft palate thickness	The largest thickness of the soft palate along a line at a right angle to PNS- P
Pharyngeal air way	5. (SPAS) Superior Posterior Airway Space	Measuring from the dorsal midpoint of the soft palate to the posterior pharyngeal surface (adjacent to Go-B Line)
	6. (MAS) Middle AirwaySpace	Line passing through P to the posterior pharyngeal surface (parallel to Go-B Line)
	7. (IAS) Inferior Airway Space	The depth of the airway along Go-B line
	8. (VAL) Vertical Airway Length	The distance between PNS and EpB

Table 2 The mean and standard deviations of pre-and post-treatment measurements of the airway, and the mean difference, p-value, of airway measurement changes. (**denotes significance at* $p < 0.05$).

Measurement	Pre-treatment	SD	Post-treatment	SD	Difference	p-value
Tongue Length (mm)	71.30	6.91	70.69	6.09	0.61	0.46
Tongue Height (mm)	30.48	2.99	30.26	2.82	0.22	0.59
Soft palate thickness (mm)	8.18	1.23	8.32	1.08	−0.14	0.43
Soft palate length (mm)	31.92	4.44	33.23	4.39	−1.30	0.053
Superior Airway space (mm)	10.16	2.63	10.80	2.19	−0.64	0.14
Middle Airway space (mm)	8.46	2.56	8.60	2.42	−0.14	0.74
Inferior Airway space (mm)	10.92	2.75	10.97	2.70	−0.05	0.92
Vertical Airway Length (mm)	57.69	6.31	59.16	5.03	−1.47	0.022*

Table 3 The mean and standard deviations of pre-treatment and post-treatment dental measurements and the means of the changes in the dental measurements. (**denotes significance at* $p < 0.05$).

Measurement	Pre-treatment	SD	Post-treatment	SD	Difference	p-value
U1 - Palatal Plane (°)	118.50	3.74	109.81	5.28	8.69	0.0001*
U1 Protrusion (U1-APo) (mm)	10.17	1.63	6.20	1.95	3.97	0.0001*
L1 to A-Po (°)	31.10	4.62	25.32	3.93	5.78	0.0001*
FMIA (L1-FH) (°)	47.79	5.44	53.74	6.69	−5.95	0.0001*
L1 to APOG (°)	6.23	2.07	3.09	1.95	3.14	0.0001*
L1-MP (°)	98.22	7.44	90.41	5.92	7.81	0.0001*
L-NB (mm)	8.84	1.65	6.10	1.90	2.74	0.0001*

premolars to be the preferred teeth to extract in bimaxillary protrusion situations (Ong and Woods, 2001). However, second premolar extraction also has been found to result in less but comparable anterior retraction with the anterior and posterior segment occupying equal amounts of the extraction sites (Chen et al., 2010, Ong and Woods, 2001). Therefore, choosing to extract the second premolars instead of the first premolars can be considered as an viable alternative pattern of extraction if it results in less changes in airway dimensions.

The variability in airway study designs and the large differences in the methods of measuring the airway changes makes direct comparisons difficult. In this study, the distance between the posterior nasal spine (PNS), and the base of the epiglottic fold, which represents the pharyngeal vertical airway length (VAR), significantly increased when comparing the pre and post cephalometric measurements. This finding is in contrast to the study by Al Maaitah et al. where they found no significant changes in all measured airway dimensions including the vertical airway length (Al Maaitah et al., 2012), and to the study by Bhatia et al. (2016) where they found no changes in the vertical airway length as a result of first premolar extractions with maximum anchorage. However it appears that using minimum anchorage to close first premolar extraction spaces increased some parameters of the upper airway (Germec-Cakan et al., 2011). In our study, reciprocal space closure was used to close second premolar extraction spaces. This reciprocal space closure allows for more mesial molar movement, which may explain the increase in the vertical airway length. On the other hand, when relying on maximum anchorage during space closure, this leads to decreases in the upper airway dimensions when closing first premolar extraction spaces (Chen et al., 2012, Wang et al., 2012, Germec-Cakan et al., 2011). This decrease in the upper airway was attributed to the posterior positioning of the tongue secondary to the retraction of the incisors. Other than the vertical airway length (VAR), all other airway measurements in our study did not significantly differ between the pre-treatment and post-treatment cephalometric radiographs. This is consistent with multiple studies which did not find significant upper airway changes due to premolar extractions (Stefanovic et al., 2013, Valiathan et al., 2010).

Due to the extraction of the second premolars in this study, the anterior-posterior procumbency of the incisors was decreased. The anterior axial inclinations of the maxillary and mandibular incisors in relation to their respective apical bases were significantly reduced in all patients, as well as the amount of linear protrusions in the sagittal plane. This is consistent to the results of Chen et al. (2010), Ong and Woods (2001) among others (Williams and Hosila, 1976, Kim et al., 2005).

Although a lateral cephalometric radiograph is a two - dimensional image of a three-dimensional structure, it has been demonstrated to be a valid tool to assess upper airway changes in patients (Pirila-Parkkinen et al., 2011, Kaur et al., 2014). This study showed that second premolar extractions do result in some changes the upper airway dimensions when done as part of orthodontic treatment. In order to better contrast these airway changes to those occurring after first premolar extractions, a controlled clinical trial needs to be conducted in which both extraction patterns are implemented. Although changes in the airway dimensions have been observed in this study and others, one important direction for future investigation is examining the effects of these changes to the airway function clinically. A shortcoming of this investigation was the fact that it was done on a sample of female adults with bimaxillary protrusion without the inclusion of a male group. In the clinic where the study was performed, the number of male patients who underwent extractions to address the esthetics of bimaxillary protrusion were fewer than their female counterparts. Male patients had a decreased demand for esthetic correction, which combined with the fact that first premolars are usually extracted instead of the second premolars, resulted in having not enough male patient numbers to be included in this study. Also, this study also did not include a non-extraction group, which is not a viable option to address those with bimaxillary protrusion. For the interested, data on non-extraction orthodontic treatment effects on the airway is published and available (Stefanovic et al., 2013, Valiathan et al., 2010). It is of value for future studies to be designed to directly compare the effects of first premolar extractions with second premolar extractions on airway dimensions for those patients undergoing orthodontic treatment to address bimaxillary protrusion. Also, there is a need to investigate the effects of first and second premolar extractions on the airway for those patients with normal incisor inclinations but crowded teeth.

5. Conclusions

The extraction of all four second premolars as part of orthodontic treatment for females with bimaxillary protrusion significantly decreases anterior- posterior incisor proclinations and protrusion, and increases the pharyngeal distance between base of the tongue and posterior nasal spine. However, it does not cause any other significant alterations in the upper airway dimensions.

Declaration of Competing Interest

The authors state the absence of any conflict of interests.

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